Overview of the FETC and EPRI Symposium on High-Temperature Particulate Cleanup for Advanced Coal-Based Power Systems

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Abstract

In April 1998, the Federal Energy Technology Center (FETC) and the Electric Power Research Institute (now known only by the acronym EPRI) organized and held a symposium entitled *High-Temperature Particulate Cleanup for Advanced Coal-Based Power Systems*. The symposium was designed to address the technology issues associated with high-temperature particulate filtration for advanced coal-based power systems. Three technical sessions and a poster session where held over a 3-day period. A tour of the Power Systems Development Facility (PSDF) was also conducted. The technical sessions included Particulate Cleanup System Performance, Filter Materials – Development and Characterization, and Dust Characterization in High-Temperature Particulate Cleanup Applications. The poster session focused on filter elements and fundamental research. A total of 23 technical platform presentations and 22 poster presentations were given. The 121 attendees at the symposium represented 12 different countries.

Introduction

High-temperature particulate cleanup is an enabling technology. Without this technology, advanced coal-based power systems will not achieve their highest goals for system efficiency, environmental performance, and low-cost electricity. To help identify and resolve the technical issues associated with this technology, the U.S. Department of Energy (DOE) and EPRI agreed to jointly sponsor a Symposium on High-Temperature Particulate Cleanup for Advanced Coal-Based Power Systems. Planing for this symposium began in April 1997. The symposium was held on April 20 to 23, 1998, at the Wynfrey Hotel in Birmingham, Alabama.

It was the intent of the symposium organizers to bring together users, developers, and researchers in this technology area to discuss ideas and issues related to this important topic. To facilitate discussion, three platform-presentation sessions, a poster session, and a panel discussion conducted on two separate days were held. The platform-presentation sessions addressed (1) particulate-cleanup system performance, (2) filter materials — development and characterization, and (3) dust characterization in high-temperature particulate cleanup applications. The poster

session was designed to highlight currently available filter elements and fundamental research. Panel discussion participants were asked to address technology issues and or opportunities relevant to the symposium topic area. Panel participants were requested to participate from pertinent technology areas, including (1) filter system suppliers — Westinghouse Science and Technology Center, and Lurgi Lentjes Babcock Energietichnik GmbH); (2) power system developers and filter system users — ABB Carbon and Foster Wheeler Development Corporation; (3) ash and char researchers — Southern Research Institute, and Institut für Mechanische Verfahrenstechnik und Mechanik der Universität Karlsruhe; and (4) filter element suppliers — 3M Ceramic Fiber Products, and SCHUMACHER Umwelt- und Trenntechnik GmbH. Panel participants were invited to represent both U.S. and foreign interests. A tour of the PSDF was also conducted during the symposium.

Formal papers were not presented at the symposium, allowing for an open discussion of the most recent and pertinent information. The proceedings from the symposium, comprising individual presentation materials, are available through EPRI..

Demographics – Who Attended

A total of 121 individuals attend the symposium. These individuals represented private corporations, national laboratories, foreign and national research institutions, universities, and government organizations. Of the 121 attendees, 39 (32 percent) were foreign nationals representing 11 countries: Australia, Canada, China, Finland, Germany, India, Japan, Korea, Spain, Sweden and the United Kingdom. Close to half (47 percent) of the individuals attending the symposium made presentations either through a poster session presentation, the panel session, or platform presentation venue. Sixteen of the presentations were from foreign nationals.

Technical Sessions

It was the intent of the symposium organizers to bring together users, developers, and researchers in this technology area to discuss ideas and issues related to high temperature particulate filtration. To facilitate discussion, three platform-presentation sessions, and a poster session were held. The platform presentation sessions addressed (1) particulate-cleanup system performance, (2) filter materials — development and characterization, and (3) dust characterization in high-temperature particulate cleanup applications. The poster session was designed to highlight currently available filter elements and fundamental research.

Presentation titles for the three technical sessions and poster session are listed below.

Session 1 – Particulate Cleanup System Performance

Operational Experiences of the TESC-BWE Filter in the Escatron PFBC Power Plant, Babcock & Wilcox Española, Spain

Performance of the Advanced Ceramic Tube Filter (ACTF) for the Wakamatsu 71 MWe PFBC Combined Cycle Power Plant — Challenge for Reliable CTF System, Electric Power Development Co., Ltd., Japan

Combustion Testing of the Westinghouse Advanced Particle Filter at the Power Systems Development Facility, Southern Company Services, Inc., USA

Hot-Gas Filter Testing with a Transport Reactor Development Unit, University of North Dakota, Energy & Environmental Research Center, USA

Particulate Cleanup for Integrated Drying Gasification Combined-Cycle Technology, Herman Research Pty Ltd., HRL Limited, Australia

LLB Hot Gas Filtration — Development and Demonstration Around the HGF for the Rheinbraun HTW Gasification Demonstration Plant Berrenrath/Germany, LLB Lurgi Lentjes Energietechnik GmbH, Germany

Westinghouse Hot Gas Filter System Development, Westinghouse Electric Corporation, USA

Slip Stream Testing of Particulate Filters at the Wabash River Coal Gasification Plant, Destec Energy, Inc., USA

Recent Advances in Computational Modeling of Particle Transport and Deposition in Hot-Gas Cleanup Filter Vessels, Clarkson University, USA

Session 2 – Filter Materials: Development and Characterization

Advanced Hot Gas Filter Development Performance and Characterization, Westinghouse Science and Technology Center, USA

Thermal Stress Fracture of Rigid Ceramics Filter Due to Char Combustion in Collected Dust Layer on Filter Surface, Tokyo University of Agriculture and Technology, Japan

Comparative Bench-Scale Test of Four Ceramic Filter Media Under High-Temperature Conditions, ABB Corporate Research, Switzerland

3M Test Methodologies for Thin-Walled, Continuous Fiber Ceramic Composites, 3M Ceramic Fiber Products Laboratory, USA

Performance of the Advanced Ceramic Tube Filter (ACTF) for the Wakamatsu 71 MWe PFBC Combined Cycle Power Plant — Modification for Thermal Stress Around Tube, Electric Power Development Co., Ltd., Japan

Properties of Ceramic Candle Filters, Southern Research Institute, USA

Nondestructive Dynamic Characterization of Ceramic Candle Filters, West Virginia University, USA

Session 3 – Dust Characterization in High-Temperature Particulate Cleanup

In-Situ Particulate Sampling and Ash Characterization Test Results from the Power Systems Development Facility, Southern Research Institute, USA

In-Situ Measurement of Cake Formation and Regeneration Behavior for Rigid Filter Media, Institut für Mechanische Verfahrenstechnik und Mechanik der Universität, Karlsruhe, Germany

Hot-Gas Filter Ash Characterization, University of North Dakota, Energy & Environmental Research Center, USA

Filter Cake Detachment from Rigid Ceramic Filters, The University of Birmingham, United Kingdom

Regenerability of Rigid High Temperature Filter Media vs. Cake and Particle Mechanics, Institut für Mechanische Verfahrenstechnik und Mechanik der Universität, Karlsruhe, Germany

Adhesive Properties of Ash Particles at High-Temperature Conditions, Tokyo University of Agriculture and Technology, Japan

Characteristics and Behavior of Ash Deposits in High Temperature Filters, Southern Research Institute, USA

Poster Session Presentations

Recrystallized Silicon Carbide (REECER™) Filter Elements for Use in High Temperature Particulate Cleanup Applications, Industrial Filter & Pump Mfg. Co., USA

Characteristics of 3M's Thin-Walled, Light-Weight Composite Filters, 3M Ceramic Fiber Products, USA

Strength Characteristics of Filter Ash Deposits, West Virginia University, USA

3-D Woven Ceramic Composite Hot Gas Filter Development, Westinghouse Electric Corporation, USA; Techniweave, Inc., USA

A New Cleanup Method for Ceramic Hot Gas Filters, Research Center Karlsruhe GmbH, Germany

The Newly Developed Cyclone Separators and Their Performances Under High Temperature, University of Petroleum, China

SiC Filter Elements for Hot Gas Filtration Applications, SCHUMACHER Umwelt- und Trenntechnik GmbH, Germany

Development of Low-Density Fibrous Media for Hot Gas Particulate Removal, The University of Birmingham, United Kingdom

New Filter Materials Development and Characterization Using Combustion Synthesis Methods, Phoenix Solutions Co., USA

Ceramic Composite Hot Gas Filter Development and Characterization, McDermott Technology, Inc., USA

Ceramic Fiber Based Filters for High-Temperature Gas Cleaning Systems, Environmental Air Filtration Limited, United Kingdom

Combustion Power Company's Granular Bed Filter, Combustion Power Company, USA

Westinghouse Standleg Moving Granular Bed Filter , Westinghouse Electric Corporation, USA

PRD-66 Hot Gas Filter Development, DuPont Lanxide Composites, Inc., USA

Ultrafoam Duplex Filter for Clean Coal Combustion: Current Developments, Ultramet, USA

Regeneration Characteristics of a Rigid Barrier Filter, U.S. Department of Energy, USA

Aerodynamic Issues Related to Large Scale Hot Gas Filtration, U.S. Department of Energy, USA

New Filter Materials "Ceramics and Metals" for Advanced Power Applications, Pall Corporation, USA

Approach to Filter System Design for Various Power System Processes, Pall Corporation, USA

Development of Material and Process for Oxide-Based Ceramic Candle Filters, Blasch Precision Ceramics, Inc., USA

Design and Development of Cross-Flow Ceramic Hot Gas Filters, LoTEC, Inc., USA, Oak Ridge National Laboratory, USA

Development and Testing of Ceramic Microfiltration Membrane Coated Honeycomb Barrier Filter Systems for Advanced Coal Combustion System Applications, CeraFilter Systems, Inc., USA

Evaluation of Iron Aluminides for Hot-Gas Filter Applications, Oak Ridge National Laboratory, USA

Advanced Ceramic Tube Filter (ACTF) in EPDC Wakamatsu 71 MW PFBC Demonstration Program Phase 1 (September 1993 - December 1997) -- An Overview of the Operation and the Improvement of the Filter Tube Material, Asahi Glass Co., Ltd., Japan

Symposium Outcomes

Some of the general results or outcomes of the symposium are presented below, grouped according to the three technical focus areas. These results or outcomes were from the technical-platform presentations, the poster session, and the panel discussion. Other symposium participants may have identified other outcomes.

Particulate Cleanup System Performance

- Barrier filter systems have been shown to be capable of filtering combustion ash at an efficiency of 99.999 percent with outlet loading of less than 1 ppm. Southern Research Institute collaborated with the PSDF to develop equipment and techniques for measuring extremely low particulate loadings under servere conditions.

- Methods and approaches for avoiding filter ash bridging have been demonstrated. These approaches include controlling inlet particle size, operating at reduced temperature (1,400 ` F), and appropriate filter system design features.

- Optimization of the coal conversion process (combustion or gasification) to control outlet particle size is critical to the successful performance of the filter system. This was highlighted by the work conducted at the Wakamatsu bubbling pressurized fluidized-bed combustor (PFBC), and the transport reactor at the PSDF. Previous tests at the Foster Wheeler circulating PFBC in Karhula, Finland, and the at Tidd bubbling PFBC have also confirmed this finding. Under combustion conditions, the optimum particle size appears to be between 10 to 20 micrometers (` m) or greater. Larger particle size distributions appear to (1) help avoid filter ash bridging, (2) produce filter cakes that are more permeable, and (3) provide bulk ash properties that are more manageable from an ash handling standpoint.

- Care must be taken to avoid thermal events in the coal conversion process or in the filter vessel. Ceramic filter elements in general can not tolerate significant thermal transients. The temperature gradient across the filter element caused by a thermal transient is the driving force for filter element failure. Mechanical properties, such as the coeffiencet of thermal expansion, strain to failure, and the coefiencent of thermal expansion, are the major material properties governing this failure mode. Temperature gradients for the monolithic type of filter elements on the order of 100 to 250 ` F can produce a failure strain, depending on the type of filter element.

- Improvements to filter-failure-safeguard devices are required. The fail-safe device (FSD) developed by the Westinghouse Science & Technology Center is currently the only FSD, which has been tested with some success.

- Capital and life cycle costs of filter systems need to be reduced. To increase the deployment potential of advanced coal-based power systems, capital and operating costs should be reduced. Present estimates suggest that filter system costs represent roughly 5 to 10 percent of the total plant cost. Increasing filter system throughput, by increasing available filter surface area and face velocity, may be the most direct way of addressing this cost issue.

- Computational modeling as a resource should be put to greater use. Computational modeling can be used to assess flow distribution and particle deposition issues.

- An effective particulate monitor is needed to detect extremely low loadings (< 10 to 30 ppm) downstream of filter systems. In the event of filter element failure or some type of clean-side particulate penetration, a particulate detection monitor is required to provide real-time particulate loading information. This is needed to prevent turbine damage and provide information, which will allow for a controlled process shutdown.

- Overloading the filter vessel hopper with ash has been shown to be destructive to filter elements. Several facilities now in initial startup have unknowingly over loaded the filter vessel ashhopper, leading to filter-element failure. One of the most successful ways to detect the buildup of ash in the vessel hopper is by properly placed thermocouples, which indicate a temperature drop when covered by ash.

- It was suggested that a set of codes and standards be established for filter systems. This would permit a common design basis and a basis for assessing performance and guarantees.

Filter Materials: Development and Characterization

- Metal-based (iron aluminde and other alloys) candle filters are being tested. Results are still preliminary, but are promising. Exposure tests have been conducted by Southern Company Services at the PSDF, Foster Wheeler in Karhula, Finland, and at the Wabash River IGCC Clean Coal Project in Terra Haute, Indiana.

- Below 1,400 ` F under combustion conditions, oxidation or creep, which has led to volume expansion and/or elongation of clay-bonded silicone carbide filter elements, does not appear to occur. This has been confirmed by laboratory testing by Westinghouse and Southern Research Institute and field testing at the PSDF and by Foster Wheeler in Karhula, Finland.

- Filter element vendors (3M and Pall) are manufacturing 2-meter long candle filter elements. Other filter manufactures also anticipate the ability to manufacture longer filter

elements. Adding a half meter to the length of these filter elements will add 33 percent more filter surface area over conventional 1.5-meter long elements with little increase in the overall length of the filter vessel.

- Several of the oxide-based composite filter elements have undergone extensive field testing at the PSDF and laboratory assessments by Southern Research Institute and Westinghouse. These elements are showing positive performance results and include the DuPont-Lanxide PRD-66, the 3M oxide composite and the McDermott oxide composite.

- West Virginia University, Schumacher, and Asahi have developed non-destructive evaluation techniques. These techniques are valuable to manufactures as well as to system owners/operators as a possible approach to assessing the post-exposure life expectancy of filter elements.

- A membrane on the inside of candle filter elements appears to be a desirable feature. An internal membrane would protect the filter element from clean-side blinding in the event that dust should reach the clean side of the filter element following the failure of adjacent filter elements.

Dust Characterization in High-Temperature Particulate Cleanup Applications

- Sampling measurements by Southern Research Institute indicate that not all particles entering the filter vessel are arriving on the filter element. This phenomenon is driven by the weight of the particles, centrifugal forces caused by a tangential flow inlet, and gravity.

- Sulfation, wetting sulfate liquids, eutectics, and fine particulate can increase the tendency to sinter and thereby form stronger ash deposits.

- Lower temperatures (less than 1,400 ` F) and larger particle sizes (greater than 15 ` m) have successfully been used to avoid filter ash bridging.

Conclusion

The organizers of the symposium were satisfied with the results of the meeting. These demographic data support the achievement of involving and gaining the participation of researchers from around the world. The presentation showed that progress is being made in the three technical areas addressed in the symposium. Technical issues relevant to these three areas have also been identified.

Excellent presentations were made by the national and international participants. The quality of the presentation material was high for both the platform presentations and the poster session. The panel session was well attended and fostered an open discussion of the technical and programmatic issues. The tour of the PSDF was well done and appreciated by symposium participants.

Finally, interested readers can obtain a copy of the symposium proceedings by contacting EPRI. The proceedings include all of the presentation material from the platform presentations and the poster session as well as information presented in the panel discussion.